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Dislocations: do you want them moving or in 3D ?

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Plastic deformation of minerals and rocks can be explained in most cases by the presence of crystal defects. Among those, dislocations represent the most efficient strain-producing actors of deformation. The physics of deformation by dislocations is complex since it is intrinsically multiscale. At the atomic scale, the dislocation core structure controls a fundamental property: their mobility. However, the plastic strain results from the collective behavior of dislocations which can be understood only at the mesoscopic scale. Multiscale numerical modeling has provided a lot of insights on these aspects in the recent years, also in mineral physics. These progress were calling for parallel developments in experiments and characterization.

Here we present two studies on dislocations in olivine deformed under lithospheric conditions based in recent developments in transmission electron microscopy.

We present plastic deformation experiments performed on olivine in situ, in the transmission electron microscope, at room temperature. The ductile behavior is made possible thanks to the very small size of the specimens (maximum dimension < 5μm) which are prepared by focused ion beam and strained in a special Micro-Electro-Mechanical-System (MEMS) device called push-to-pull (PI 95 TEM PicoIndenter from Hysitron). By performing experiments under constant load, the velocity of [001] screw dislocations has been measured as a function of stress. This mobility law has then been introduced in a Dislocation Dynamics model to determine the stress strain curves.

We present also some recent developments on electron tomography of dislocations performed on olivine. The difficulty is here to keep diffraction conditions strictly constant over a wide range of tilt acquisitions. We present some examples obtained by imaging dislocations in weak-beam dark-field using precession electron diffraction. The analysis of dislocation microstructures in 3D is used to characterize dislocations glide planes and the interaction mechanisms between dislocations.